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MINING SOFT HEMATITE BY OPEN STOPES AT MINE NO. 1, MENOMINEE RANGE, MICHIGAN

BY

LUCIEN EATON

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MINING SOFT HEMATITE BY OPEN STOPES AT MINE NO. 1, MENOMINEE RANGE, MICHIGAN[1]

By Lucien Eaton [2]

This paper describing the mining practices at Mine No. 1, Menominee Range, Mich., is one of a series being prepared by the Bureau of Mines on mining practices, methods, and costs in the various mining districts of the United States. It is felt that the publication of this information will be of interest and value to the mining industry at large and especially to operators whose mining conditions are similar to those described.

ACKNOWLEDGMENTS

The author is indebted to the superintendent, engineer, and mining captain of Mine No. 1 for much of the information presented.

HISTORY

Iron ore was discovered in the Menominee district as early as 1880, but development has been slow partly on account of the character of the ore, which was not as desirable as that of some of the other ranges, and partly on account of the absence of outcrops. Exploration was quite active 20 years ago.

Mine No. 1 was discovered in 1913 by diamond-drilling, and the shaft was sunk in 1916. The operation of the mine has been rather intermittent, as the ore has not always commanded a ready market. The method of mining used has been well suited to this condition, and the stopes have not suffered during periods of idleness.

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2 - One of the consulting engineers, U. S. Bureau of Mines.

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GEOLOGY

The rocks in the district are pre-Cambrian, and are overlaid by thick deposits of bowlder till, sand, and gravel of Pleistocene age. The iron-bearing formation is the Vulcan member of the Michigamme slate, which in turn belongs in the Upper Huronian series of the Algonkian system.

The Vulcan formation consists of ferruginous cherts and slates and of iron ore interbedded with slates and unaltered iron-bearing rocks. There has been much folding on both a large and small scale, and the occurrence of the ore is closely connected with it. As a consequence the ore bodies are quite irregular in outline, but as a general rule dip at a high angle. The irregularity in the shape of the ore bodies and the variation in their chemical characteristics has materially increased the amount of development required in mining the ore.

PHYSICAL CHARACTERISTICS OF ORE AND ENCLOSING ROCKS.

The ore is a firm but not very hard hydrated hematite. It stands well in large stopes and is not affected by exposure to the air, but is hard to break in small openings.

The ferruginous cherts are much harder than the ore and are quite abrasive. They also stand well. The slates that form the footwall and hanging wall, however, swell on exposure to the air, and, as they contain appreciable amounts of pyrite and carbon, are apt to catch on fire if exposed in dry places. They are often interbanded with the ore near the contacts, so that a layer of mixed ore can, without loss, be left to protect the contact.

The boundaries of the ore, except where it is in contact with the slates, are largely commercial; that is to say, the gradation from clean ore to ferruginous chert is gradual, and the limits of mining are determined by analysis.

Although the ore bodies in geleral follow folds in the slate, the dip is usually steep. The choice of mining method was largely governed by this fact, as well as by the ability of the ore to stand in large stopes.

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GENERAL ITEMS

The mine is served by the Chicago & North Western Railway, with ore docks at Escanaba, Mich., where water transportation is available during the summer months to Lake Erie ports and the Chicago District. As the lakes are frozen in winter, the ore must be stocked from November 15 to April 15.

The ores of the district average rather high in sulphur and phosphorus, and do not command the full market price. Cheap methods of mining are therefore required. The tendency of the slates toward spontaneous combustion and the intermittent operation to which the mine has been subject are conditions unfavorable for top-slicing or caving methods, and experience has proved that the method of mining chosen - namely, substoping in rooms with pillar support - is admirably suited to meet the conditions imposed.

METHODS OF PROSPECTING AND EXPLORATION

In looking for ore on surface there are few, if any, outcrops to be used as a guide, and preliminary exploration is done by magnetic surveys on lines running north and south 660 feet apart, on and parallel to the Government survey section lines. Readings are taken at frequent intervals with dial compass and dip needle, and from these readings the boundaries of the ore formation can be mapped.

Cross sections are then made by diamond-drilling at favorable locations. Standpipes are driven through the glacial drift to the ledge at intervals, usually on lines at right angles to the strike of the formation, and in this way the contacts of the ore formation are definitely located. Deeper drilling is then continued in the iron formation with the diamond drill.

Prospecting underground is done by drifting and raising, as well as by diamond drill and by "deep hole" drilling. This last method of exploration is used mainly to determine the limits of the ore body, and drilling is done from a drift or raise in the ore outward toward the contacts with the surrounding rocks. For this purpose it works well, but it is not so successful in drilling through the hard and abrasive ferruginous cherts.

In "deep hole" drilling a large hammer drill with a powerful independent rotation is mounted on a cross arm between two columns, and the hole is drilled at a slight angle upwards, using standard cross bits

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of large diameter. As the hole is deepened, hollow extension rods are screwed on the drill steel. Water under high pressure is forced through the rods and bit, and brings back the cuttings, which are caught in a sludge box. Care must be exercised to prevent too much loss of gauge in the bit, as this limits the depth to which the hole can be drilled.

METHODS OF SAMPLING AND ESTIMATION OF TONNAGES AND VALUES

Production samples are checked by samples taken at intervals from the stopes, drifts, and raises, and the commercial limits of the ore are determined by samples taken from drifts and raises, from "deep hole" drill holes, and from diamond-drill holes.

The standard methods adopted by the mining companies of the Lake Superior region and by the Lake Erie chemists are used on surface. These methods are fully described in "Methods of the Chemists of the U. S. Steel Corporation for Sampling and Analysis of Iron and Manganese Ores," third edition, from which pertinent extracts are published in the 1927 edition of Crowell and Murray's "Iron Ores of Lake Superior."

Tonnage is estimated by calculating volumes from the data given by geological maps and cross sections, on which all of the information available is posted. A factor of 12 cubic feet per ton is used, and a deduction of 10 per cent for rock and 10 per cent for loss is made. Pillars and stopes are laid out on the maps, and deductions are made for the supporting pillars.

Analysis is estimated from the results of sampling in drifts, cross-cuts and raises, and from the records of diamond-drill holes and "deep hole" drill holes. The dried ore averages 57.50 per cent iron and .40 per cent phosphorus.

METHODS OF DEVELOPMENT

General Development. - The mine is opened by a vertical shaft 1,250 feet deep. The shaft is timbered with wood sets and lath. There are two hoisting compartments in use, a cage and skip being operated in balance. A plan of the shaft is shown in figure 1.

The first level is at a depth of 200 feet, the second at 300 feet and the fourth at 400 feet. The sixth level is at 950 feet, and the eighth level at 1,200 feet.

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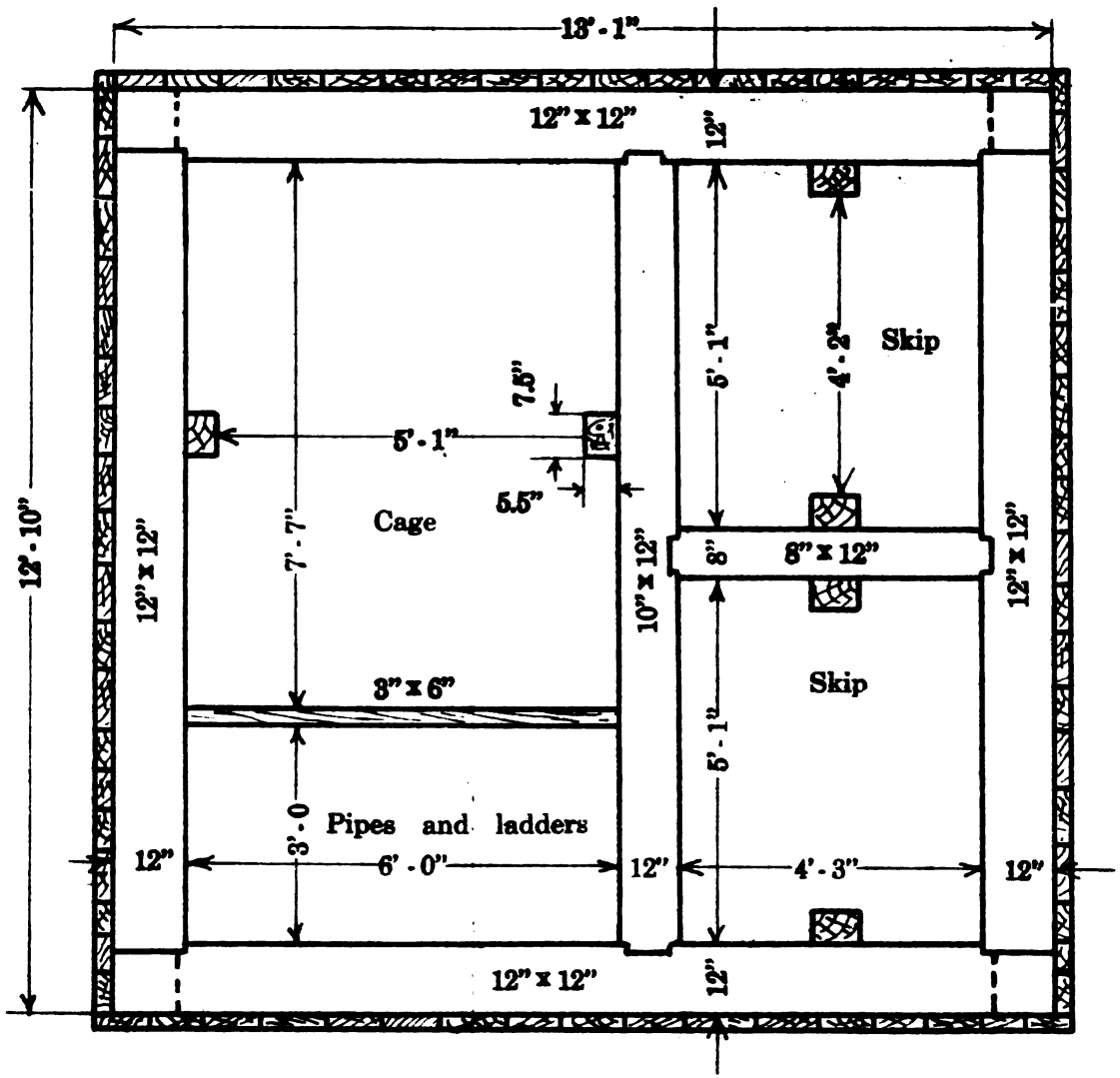

Figure 1.- Plan of shaft

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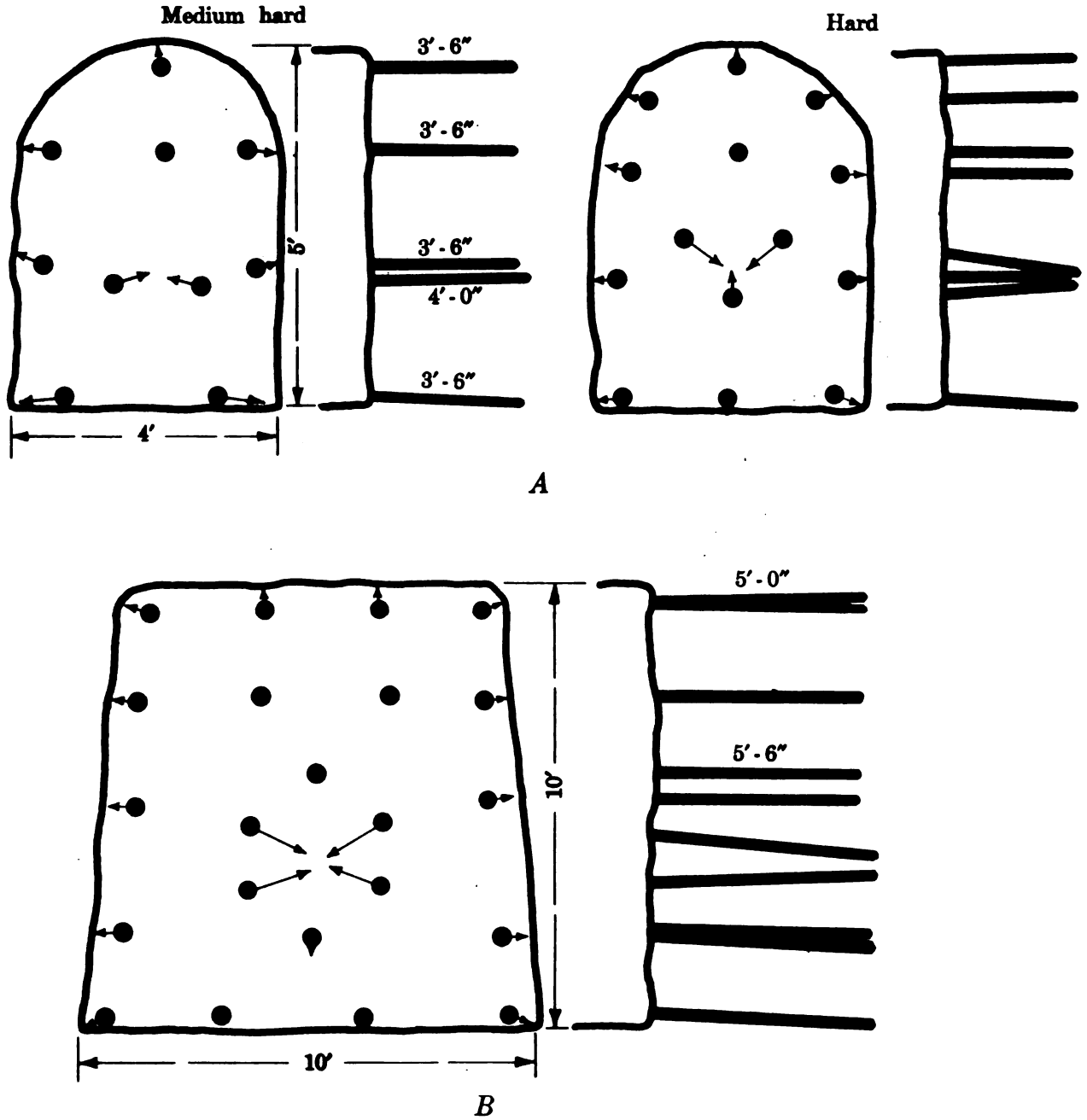

Figure 2. — *A*, Sublevel dog drifts; *B*, timbered motor drift

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Development Details. - Typical rounds used in blasting main drifts and sublevel drifts are shown in figure 2.

In the main drifts 3½-inch wet hammer drills, using 1¼-inch round hollow steel with lugs, are mounted on a 3-inch horizontal bar. Standard double-taper cross bits with 90° cutting edge, and 5° and 14° taper on the wings are used. Mucking is done with a mechanical air-operated loader, emptying into 36 cubic foot rocker-dump cars. The crew consists of three miners, a shovel runner, and a motoroman. Drifting is done on contract. The miners pay for all explosives and some tools, and the company furnishes drills and drill steel, loader, cars, and locomotive, and pays the man who runs the locomotive.

In the small drifts on the sublevels drilling is done with wet jackhammer drills weighing about 50 pounds each, using seven-eighths-inch hexagon hollow collared steel. The drill is used unmounted, but when in use is supported on one end of a vertical 2-inch plank cut to the proper length. Three of these planks are used, varying in length from 2 to nearly 5 feet. The plank merely supports the weight of the machine, and, not being fastened in any way, does not hinder the movement of the steel in the hole.

The sublevel drifts are driven on contract, the price varying from $3.50 to $5 per foot, depending on the hardness of the ground and the distance from the chute. The broken dirt is trammed in a wheel barrow and dumped into the nearest raise.

Raises are about 5 feet in diameter and are untimbered. They are also driven on contract, the price varying between $3.50 and $5 per foot.

STOPING.

A typical main level plan in shown in figure 3. Figure 4 is a plan of a sublevel.

A drift is driven to the ore, and parallel extraction drifts 33 feet apart on centers are driven in the ore under the ore body to be mined. These drifts are 8 by 8 feet in cross section and are timbered and lagged. At 25-foot intervals on each side of the drift, raises are

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put up and chutes built. These raises are staggered, so that there are chutes on alternate sides of the drift at 12.5-foot intervals along the center line. Most of these raises extend only 25 feet above the floor of the level. As the drifts are 8 feet wide, the pillars between the drifts are 25 feet wide, and the chutes reach the bottom of the stope at the corners of squares about 20 feet on a side. Some of the drifts and some of the raises have to be in rock for part of their length.

Near one end or side of the ore body, usually the footwall side, a manway and supply raise is put up to the top of the ore or to the next level, and at the other end of the ore body one of the raises in each room is carried up as far as the ore is to be mined. This raise will be used as the first chute.

The sublevel interval is 25 feet, as shown in Figures 5 and 6, which are vertical cross sections. On each sublevel, drifts are driven 25 feet apart center to center parallel with the extraction-drifts on the main level, and are connected with the manway at one end and with a chute at the other end. These drifts are untimbered and are small in cross section, being 6 feet high and approximately 4 feet wide. In the narrow parts of the ore body, where the ore is mined over its full width, there is only one drift, and crosscuts are driven right and left from this drift at 25-foot intervals to the limits of the ore. These crosscuts are for exploratory purposes only, and are not used in mining.

Mining starts in the hanging-wall raise, the one that has been put up for the full height. This raise is enlarged below the first sublevel into an inverted cone or mill-hole; back holes are then drilled upwards around the raise on the first sublevel, and down holes on the sublevel above, and the ore is blasted into the chute until it has been stoped out to the full width of the room. The ore between the second and third sublevels is then stoped around the raise in the same way, and this work is continued on successive sublevels until the enlarged opening has been carried up to the top of the ore. In the meantime the next chute has been opened out into a cone below the first sublevel, and, as the face of ore on the successive sublevels is beaten back from the first chute, the broken ore falls into the second chute. After the stope has been opened for the full height in the first chute, one gang of miners can work on each sublevel, breaking the ore into the stope, and keeping the face approximately vertical. The chutes are coned-out below the first sublevel in advance of stoping, so that as the face is beaten back there is always a cone ready for the ore to fall into.

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On each sublevel the work is carried on substantially as follows: First a short cut is taken on one side of the drift, the holes being drilled at right angles to the axis of the drift. When this is blasted, there is room to set up and drill longer holes to right and left in the same direction to the limits of the room or, in the wider rooms, to the limits of the ore to be mined from this drift. When these holes are blasted there is a shelf about 6 feet wide across the face of the room. Standing on this shelf the miners drill uppers into the back of ore above them and down holes in the bench below. The sublevels are so spaced that the upper holes from one sublevel and the down holes from the next one above will take out the whole thickness of the ore between the subs.

UNDERGROUND TRANSPORTATION

Ore is transported in 36-cubic foot rocker-dump cars on a 30-inch gauge track laid with 40-pound rails. The cars are hauled in trains of 10 cars by a 6½-ton twin-motor electric trolley locomotive. Both cars and locomotive are equipped with half-size automatic couplers.

The ore is drawn from chutes into these cars, except in main level drifting where shoveling is done with a mechanical air-operated loader or with a scraper and slide.

The cars are dumped over a grizzly into a pocket at the shaft. The pocket holds two cars, which is one skipload. Grizzly bars are set 10 inches apart, and chunks are broken with a sledge or with a pneumatic "chunk buster," which is kept at the pocket all the time.

ADVANTAGES OF METHOD OF MINING USED

The method of mining in use at Mine No. 1 has many advantages. The miners are always standing on firm ground and under a low back, and if they wear life belts are in little danger of falling into the stope. The holes blasted have always an open face to break to, thus insuring maximum efficiency of powder. The ore broken is drawn off from the stope immediately, and large accumulations of broken ore underground are avoided. The number of drawing points is small, and this also promotes efficiency in loading.

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Furthermore, this method of mining facilitates the mining of ore bodies of irregular outline, and makes possible both the leaving of lean material as pillars and the mining of enrichments in the walls.

The percentage of extraction averages at present 75 per cent; before the mine is abandoned this will be increased by the extraction of some of the pillars.

VENTILATION

Ventilation at the mine is natural and is good. The downcast air enters the mine through an idle shaft which is used as a second outlet. The hoisting shaft is upcast, which is of great advantage in the winter months.

The only unusual feature of the ventilating system is the large number of Murphy eductors in use. These are small inspirators in which a small jet of compressed-air causes a large volume of free air to move through a short piece of 3-inch tubing. These eductors aid materially in blowing out powder fumes after blasts in the chutes.

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MINING COSTS

Table I. - Summary of Costs

Name or Number of Mine: No. 1, Menominee Range, Mich. Period Covered: Year of 1928.
Long Tons ore hoisted during period: 200,000.
Mining Method: Sublevel stoping.

Underground Costs per Long Ton of Ore Hoisted

	1. Labor	2. Supervision	3. Compressed air drills and steel	4. Power cost	5. Explosives	6. Timber	7. Other supplies	8. Total
Development:	$	$	$	$	$	$	$	$
In ore	.0832	.0062	.0107		.0306	.0056	.0030	.1393
In rock	.0345	.0036	.0206		.0087	.0038	.0007	.0719
Mining	.2461	.0312	.0798		.0897	.0094	.0106	.4668
Transportation (underground)	.1124	.0022		.0454			.0126	.1726
General underground expense	.0236	.0004		.0247			.0035	.0522
Surface expense (directly applicable to underground operation)	.0179	.0009					.0087	.0275
TOTAL	.5177	.0445	.1111	.0701	.1290	.0188	.0391	.9303

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II - SUMMARY OF COSTS IN UNITS OF LABOR, POWER & SUPPLIES.

Name or Number of Mine - No. 1, Menominee Range, Michigan. Period Covered- Year 1928.

Tons Ore Mined and Hoisted - 200,000 tons.

Mining Method - Sub-level Stoping.

	DEVELOPMENT[1]	MINING(STOPING)[1]	TOTAL[1]
A. Labor (Man-Hours Per Ton).			
Breaking (Drilling and Blasting)	.088	.353	.441
Timbering,	.010	.038	.048
Mucking,	.001	.011	.012
Haulage Hoisting,	.036	.142	.178
General,	.014	.056	.070
Supervision,	.008	.028	.036
Total Labor Underground,	.157	.628	.785
Average tons per man per shift,		12.74	10.19
Labor, percent of total cost,	15%	47%	63%
B. Power and Supplies.			
Explosives (lbs. per ton),	.2064	.6191	.8255
(kind and grade),	50% & 60%	40%	
Timber (B.M.),	.0076	.0230	.0306
Total Power (In K.W.Hr. PerTon).			
1. Air Compression,	1.50	4.40	5.90
2. Hoisting,	.83	2.36	3.34
3. Pumping,	.47	1.42	1.89
4. Lighting,	.12	.35	.47
Total,	2.97	8.83	11.80
C. Percent of Total Cost. Supplies	9.5%	28.5%	38.0%
Labor & Supplies Percent of Total Cost	24.5%	75.5%	100.0%

1 - Based on total tonnage hoisted.

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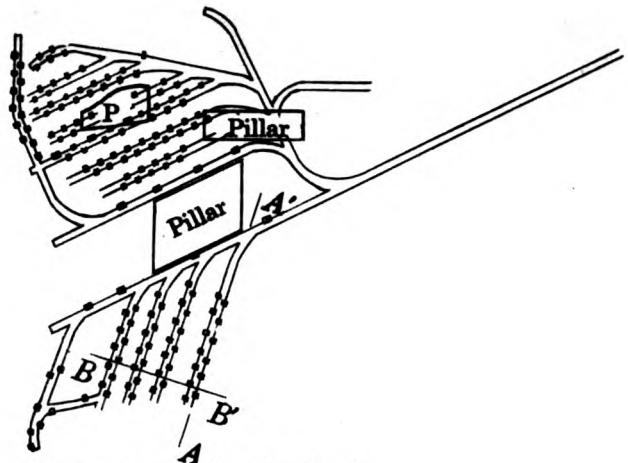
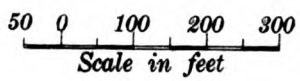


Figure 3.— Typical level plan



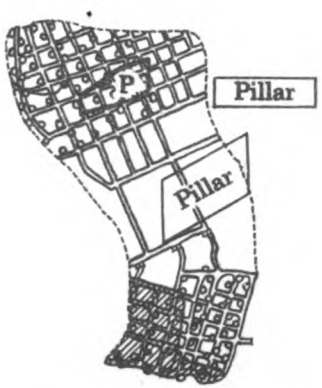


Figure 4.— Plan of sublevel

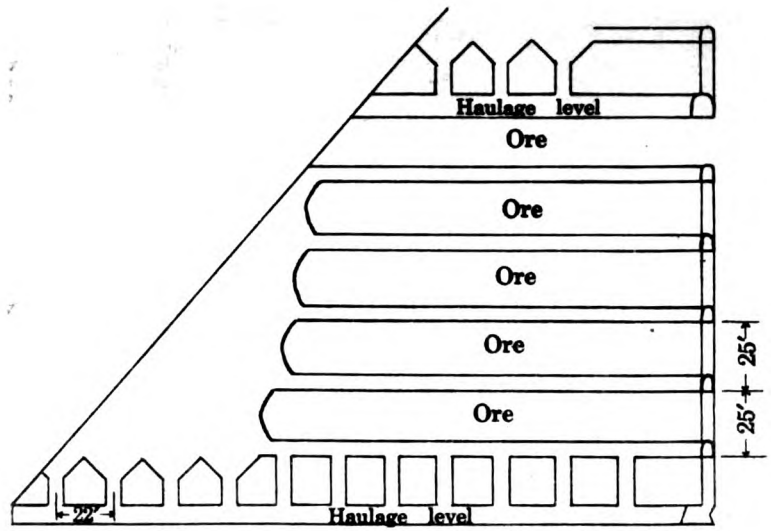


Figure 5.—Section $A-A'$. Not drawn to scale

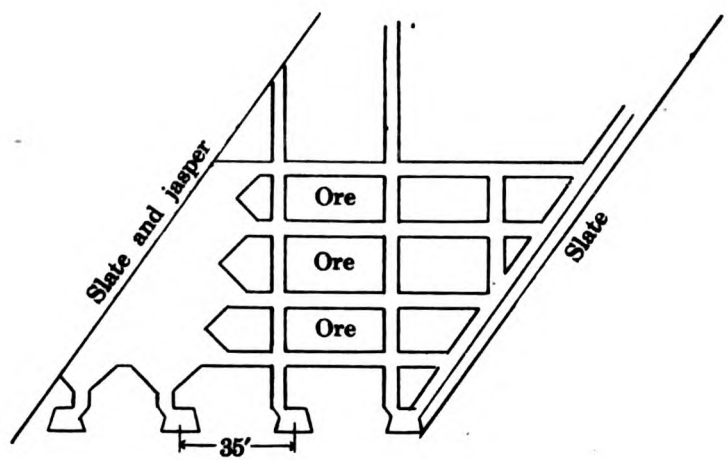


Figure 6.—Section $B-B'$. Not drawn to scale

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